

DEHYDROXYLATED ALUMINIUM SILICATE BASED MATERIAL, PROCESS AND INSTALLATION FOR THE MANUFACTURE THEREOF

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BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a material based on aluminium silicate, having pozzolanic properties, especially in Portland cement-based systems (mortar, concrete, paste, etc.). It concerns more particularly a dehydroxylated aluminium silicate-based material, which may be obtained by dehydroxylation treatment of clay mineral particles, in order to obtain or to enhance reactivity as an additive or addition (of the pozzolanic type) in Portland cement based systems (mortar, concrete, paste, etc.).

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DESCRIPTION OF THE BACKGROUND

When added to Portland cement-based systems, aluminium silicate in the form of metakaolin reacts with the calcium hydroxide released by cement hydration to form calcium silicate hydrates (C-S-H). This is the pozzolan reaction. Metakaolin, as an artificial pozzolan, is often used in glass fiber reinforced cement to consume lime, and then, decrease the pH of the pore solution, allowing a better durability of the glass fibers.

This aluminium silicate in a reactive form can be obtained by a thermal calcination treatment of kaolin or kaolinite, generally from an argillaceous starting material. The endothermic reaction is as follows:



It takes place at a temperature of about 500 to 650°C, depending on the nature of the initial clay.

The industrial implementation of this treatment needs to satisfy two requirements: treating the argillaceous material thoroughly in order to convert all the kaolin into metakaolin, without the temperature of the treated material reaching the breakdown temperature of metakaolin, which may be converted (during an endothermic reaction) at about 900°C into an unreactive crystallised form such as mullite or cristobalite.

In one known industrial technique, clay in the form of pellets is treated in a plate furnace, in which each stage heated by burners to a given temperature comprises a plate on which a substantial thickness of clay is deposited, and scraper arms which ensure that the clay is exposed to the temperature of the stage for the desired time and which direct the material treated on one plate to the next plate. Typically, these installations impose a temperature gradient which increases in the circulation direction of the clay, of the order of 500 to 750°C at the plates. In order to achieve these temperatures, the burners heat walls locally to much higher temperatures, and the components of the furnace, in particular walls and arms, which are subjected to high stresses need to be made of refractory materials with good thermal stability and/or need to be provided with a cooling system. Furthermore, the residence time of the materials in the furnace is very long and entails very significant energy consumption and, lastly, the fine particles which are produced by attrition of the pellets are entrained by the firing gases, therefore necessitating a treatment to remove dust from the fumes.

In another known technique, which is referred to as "flash calcination", clay particles are subjected to considerable temperature gradients, so as to reach the treatment temperature almost immediately. In practice, the clay particles are placed in an environment whose temperature may be as much as 900 to 1000°C, or more, for a very short time, so that the heat exchanges bring the particle to the desired temperature of the order of 500-600°C. According to certain embodiments, the calcination furnace comprises an enclosed space in which a burner that produces the desired temperature is installed. This type of furnace involves the risk that the particles may come into contact with the flame of the burner and exceed the desired treatment temperature. Another type of flash calcination furnace, described in particular in US-A-6 139 313, comprises a chamber for treatment by a toroidal gas stream, in which a very high-temperature plasma is formed by injecting fuel into a hot gas stream created upstream of the treatment chamber. The critical components of the furnace are once more exposed to very high temperatures, which necessitates complicated cooling devices.

The pozzolanic reactivity (PR) of the dehydroxylated material is determined by the amount of calcium hydroxide consumed by the pozzolan in a pozzolan-calcium hydroxide mixture. It is used to determine the kinetics of the reaction in normal temperature conditions.

The Chapelle test value, determines the potential of the pozzolan to consume calcium hydroxide after a long time. It is obtained at higher temperature, to accelerate the pozzolanic reaction.

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SUMMARY OF THE INVENTION

It is the purpose of the present invention to provide an improved aluminium silicate-based material.

The material of the invention is characterized by a high kinetic for the pozzolanic reaction. As a consequence, when the material is added in a Portland cement-based product, it accelerates the strength acquisition compared to Portland cement-based product containing commercially available metakaolin. The Portland cement-based product can be demoulded and put in service earlier.

More particularly, the material of the invention is characterized in that the pozzolanic reactivity (PR) following a 3-day cure is at least 50%. In optimised conditions, the PR following a 3-day cure is at least 62%.

The higher kinetic is such that the pozzolanic reactivity following a 7-day - cure is significantly improved. According to the invention, the PR following a 7-day cure is at least 92%.

In optimised conditions, the PR following a 7-day cure is at least 94%.

This improved material may be obtained by a process for dehydroxylation treatment of aluminium silicate, in which particles containing aluminium silicate are exposed to a temperature of at least 500°C, wherein the particles are in the form of a dry powder, and the dry powder is transported in a gas stream at a temperature of from 600 to 850°C, for a time which is sufficient to achieve the desired degree of dehydroxylation.

In such process, which is also an object of the invention, the material containing aluminium silicate, as a powdered form, reacts astonishingly rapidly in the transport gas, the temperature of which is nevertheless much less than the usual treatment temperatures of a "flash" calcination treatment, so that the process provides a thermal dehydroxylation treatment which is inexpensive to implement in terms of both the energy required and the materials used to make the treatment devices. Moreover, the dehydroxylated material has a quicker pouzzolanic reactivity than aluminium silicate dehydroxylated with conventional processes.

To provide a specific reference, the dry powder generally has a particle size of less than or equal to 100 μm , i.e. all the particles which form it have a size characterised by dimensions (diameter or apparent diameter) of less than or equal to 100 μm . Preferably, it is essentially composed of particles with dimensions of less than or equal to 80 μm . It advantageously comprises at least 60% by weight of particles with a dimension of less than 20 μm , and preferably a small quantity (for example less than or equal to 5%) of particles with dimensions greater than 40 microns (95% < 40 microns).

Advantageously, the powder is formed from a hydrated base paste containing aluminium silicate, in the following way: the base paste is reduced into fragments, and the fragments of base paste are disaggregated by mechanical action in the presence of a hot gas at a temperature of the order of 500°C to 800°C.

Unexpected in this process is that a simple mechanical operation of grinding, milling, kneading or the like, carried out in the presence of a hot gas with a temperature of greater than or equal to 500°C, which would usually be envisaged for drying a hydrated material, makes it possible not only to evaporate the water of hydration of the base paste, but furthermore to initiate separation of the bound water of the aluminium silicate, forming metakaolin. This operation is performed by transporting the powdered products with hot gas whose temperature (500 to 850°C) is precisely defined so as, on the one hand, to permit sufficient progress of the reaction (temperature and transport time) and, on the other hand, not to form crystallised products that are stable in the presence of lime (upper limit of the temperature).

The mechanical action envisaged according to this process is preferably an action suitable for separating the particles constituting the mineral material of the base paste, in order to provide the dry material with its "natural" particle size distribution. This is why the term disaggregation is used here. Likewise, when it is used in the present description, the term grinding comprises any "gentle" type of action, in particular such as attrition, and is not limited to an operation suitable for reducing the particle size of a material by breaking up its constituent particles.

The temperature of the hot gas used in the disaggregation step is chosen to be less than 800°C, in order to avoid subsequent conversion of metakaolin into an unreactive form, but it is desirably as high as possible for rapid drying of the

hydrated base paste. The temperature may be chosen within the range dependent on the water content and the inherent characteristics of the primary material, which are associated with its composition and therefore the quarry or source which is used. The precise temperature at which a kaolin is converted into metakaolin can be determined by subjecting the primary material to differential thermal analysis (DTA), the metakaolin transformation peak generally lying between 500 and 550 or 600°C. The temperature of the hot gas may advantageously be chosen to be of the order of 600 to 750°C, in particular 650 to 700°. This refers to the temperature of the gases after mixing and introduction of the argillaceous particles. It is therefore beneficial for the hot gas to be supplied at a temperature as close as possible to the transformation temperature, although this temperature should be as high as possible (850-900°C) while being below the threshold corresponding to the reaction for conversion into mullite.

The conditions of the disaggregation step according to the invention permit substantial removal of the water present in the hydrated base paste. Typically, starting with a base paste having a water content of less than 30% by weight, in particular of the order of from 15 to 30% by weight, the disaggregated dry powder generally has a residual water content of the order of from 0 to 1% by weight.

Advantageously, the disaggregation is carried out by forcing the fragments of paste and the hot gas between grinding components. This produces a maximum surface area for contact between the paste and the hot gas, which promotes the exchange of heat and permits almost immediate drying.

By virtue of these drying conditions, the material of the base paste is reduced into a powder having the dimensions of its constituent particles. In general, the dry powder has a particle size of less than or equal to 100 µm, preferably less than or equal to 80 µm. It advantageously comprises at least 60% by weight of particles with a dimension of less than 20 µm, and preferably a small quantity (for example less than or equal to 5%) of particles with dimensions greater than 40 microns.

According to the primary material which is used, in particular when it is a natural material such as clay, the disaggregation step is followed by a step of separating coarse particles such as sand, in particular using a cyclone, after which the dry powder intended to undergo the heat treatment is recovered.

According to the primary material which is used, a dry powder containing aluminium silicate that may be partially dehydroxylated during the grinding–drying operation can be obtained. The degree of dehydroxylation can be assessed by the reactivity in the "Chapelle" test, which consists in evaluating the quantity of CaO potentially consumable by the mineral material after a long time, hence defining the potential pozzolanic reactivity of the mineral addition. In this test, which is described by R. Largent in *Bulletin de Liaison des Laboratoires des Ponts et Chaussées* [journal of the laboratories of the French higher educational institute for civil engineering] No.93 (January-February 1978), 63-64, the mineral material and lime suspended in air are placed in contact for sixteen hours at close to the boiling point. The high temperature accelerates the pozzolanic reaction. After cooling, the amount of lime that has not reacted is determined. The result is expressed in g per 1 g of mineral material.

In order to achieve a high degree of dehydroxylation with a Chapelle test reactivity of at least about 0.7 to 0.8, the invention provides a step of heat treatment by transporting the dry powder in a hot gas stream at a temperature of from 600 to 850°C, for a time which is sufficient to achieve the desired degree of dehydroxylation, without the temperature of the particle reaching the zone for mineral conversion into mullite.

Analysis of the curves provided by DTA makes it possible to identify and quantify precisely both the reaction temperatures (determination of the minimum and maximum temperatures) and the kinetics of kaolin conversion into metakaolin, which is useful for determining according to the invention the pairing of temperature_transport time of the kaolin in powder form. The temperature of the hot gas determines (by using the DTA results) the time of transport (contact between the gas and the powder) which is necessary for converting the kaolin into metakaolin. For instance, in the case of a kaolin which was studied, the transport time needed to achieve 80% dehydroxylation is 13 seconds with a temperature of 600°C, whereas it is advantageously reduced to 0.1 s with gases at about 800°C. It is noteworthy that the heat treatment conditions of the elementary kaolin particles when placed in a dilute flow are substantially different from those which are produced in measuring instruments of the DTA type, where the sample is placed in small crucibles. This geometrical arrangement is also modified by the

presence of a relative humidity in the crucibles of the equipment which is greater than that prevailing in the dilute flow.

The powder which is to be subjected to the hot treatment may be treated directly after the disaggregation, if the latter is carried out on the site of the heat treatment, or alternatively after a step of intermediate storage on site or in a separate installation for preparation of the powder.

In the former case, it is possible to recover the powder with the hot gas stream when it leaves the disaggregation, then to transport the powder through the rest of the hot treatment, with optional supply of additional heat in the form of an auxiliary hot gas stream or other heating means, in order to raise the gas to a temperature ranging from 600 to 850°C.

In the latter case, the powder is introduced into a second hot gas stream at a temperature of from 600 to 850°C.

In either variant, the temperature of the hot gas may advantageously be controlled during the transport of the dry powder. The control may consist in imposing a temperature gradient on the gas and the powder, or, conversely, in keeping the temperature of the hot gas constant during the transport of the dry powder.

At the end of treatment, the dehydroxylated dry powder may be recovered by various means, in particular by filtration.

The invention also relates to an installation for the dehydroxylation treatment of aluminium silicate, characterised in that it includes a conduit supplied with a hot gas stream at a temperature ranging from 600 to 850°C, means for introducing a dry powder containing aluminium silicate into the conduit, and means for transporting the dry powder in this conduit.

According to other characteristics:

- the installation comprises means for comminuting a hydrated base paste containing aluminium silicate into fragments, a grinder-dryer which disaggregates the fragments of base paste by mechanical action in the presence of a hot gas at a temperature ranging from 500°C to 800°C, and means for collecting a dry powder downstream of the grinder-dryer;

- the grinder-dryer includes a grinding zone with grinding components and passages for the hot gas in the said grinding zone;

- the grinding components comprise at least two parallel discs carrying fingers projecting on their opposing surfaces, and in that the passages for the hot gas are the spaces between the fingers of the discs;
- the installation comprises separation means, such as a cyclone, at the
5 outlet of the grinder-dryer;
- the installation comprises means for intermediate storage between the grinder-dryer and the conduit;
- the conduit is supplied with hot gas by a burner whose flame is contained outside the conduit;
- 10 - the conduit is equipped with external heating means, such as electrical heating elements and/or a heating jacket;
- the heating means consist of at least one intake for a gas which, by combustion at a wall of the installation, makes it possible to maintain a wall temperature of close to 800°C
- 15 - the installation comprises, downstream, means for collecting powder by filtration.

BRIEF DESCRIPTION OF THE DRAWINGS

Other details and characteristics of the invention will emerge from the
20 following detailed description of an exemplary embodiment of the invention, which is provided with reference to the appended drawings, in which:

- Figure 1 represents a diagram of an installation according to the invention;
- Figure 2 represents a schematic sectional view of a grinder-dryer
25 suitable for forming part of the installation in Figure 1;
- Figure 3 presents in detail the grinding components of the grinder-dryer in Figure 2.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

30 In this example, the process according to the invention is used to treat kaolin clay, in order to convert aluminium sulphate into metakaolin.

To that end, the installation in Figure 1 may be used. It should be pointed out that the representation in Figure 1 is schematic, that the elements are not represented to scale, and that it does not limit the invention in any way, in

particular as regards the arrangement of the various stations or the disposition or the orientation of the lines for circulating the materials.

This installation essentially comprises a clay storage hopper 1, a comminuter 2, a grinder-dryer 3, optionally a separation cyclone 4, optionally a storage container 5, a transport conduit 6, a cooling station 7 and a powder collection filter 8.

The clay contained in the hopper 1 is in the form as it is produced when extracted from the quarry, generally in the form of blocks of a hydrated base paste whose dimensions may be as much as about ten centimetres. In the initial state, it has a water content which may range, for example, from 15 to 30% by weight.

The comminuter 2 delivers fragments of base paste with reduced dimensions, in particular of the order of several centimetres, into the grinder-dryer 3, for example by means of a feed screw.

The grinder-dryer 3 is supplied with a hot gas stream produced at 9 by a burner 10 and a fan 11, the stream being transported to the grinder-dryer through a conduit 12. The flame of the burner 10 is regulated so that the temperature of the hot gas stream in the conduit 12 is of the order of from 500 to 800°C, preferably of the order of from 600 to 750°C, and in particular of the order of from 650 to 700°C.

The fragments of base paste are introduced into the hot gas stream at 13 with a rate which is controlled, for example, by the rotation of the screw, just before the conduit 12 meets the grinder-dryer 3.

The disaggregation step will be understood more clearly with reference to Figures 2 and 3, which respectively represent a type of grinder-dryer that can be used according to the invention, seen in section on a vertical plane in the axis of the line of the part of the installation represented at the bottom in Figure 1, and a detail of this grinder-dryer seen in exploded perspective. This type of grinder-dryer is marketed, in particular, by CMI-HANREZ.

The grinder is essentially composed of an enclosed space 14, with a shaft 15 turning inside, which is driven by schematically indicated means 16 and which carries at least one disc 17 provided with at least one series of fingers 18 that project on at least one plane face of the disc and are preferably arranged in a ring around the periphery of the disc 17. The enclosed space includes two disc-shaped walls 19, 20 which are parallel to the disc 17 and which, on their surface opposing

the plane faces of the disc 17, carry at least one series of fingers 21, 22 that are arranged in a ring around the periphery of the discs 19, 20. The series of discs are arranged concentrically, and their length is chosen so as to form chicanes between the fingers of two neighbouring series.

5 During operation, the rotation of the disc 17 drives the fragments 23 of base paste towards the periphery of the enclosed space 14. On the first face of the disc 17, the fragments pass through the chicanes formed between the fingers 18 and 22, then they pass along the periphery of the enclosed space 14 towards the other face of the disc 17 and, on the other face of the latter, they pass through the
10 chicanes formed between the fingers 18 and 21. The effect of this path between the grinding fingers, which are very close together, is to knead or triturate the clay paste.

 The hot gas stream 24 follows the same path, which is indicated by the arrows, and it envelops and penetrates the fragments of base paste, with a
15 considerable surface area for exchange between the hot gas and the paste. This large exchange surface area permits very rapid, almost immediate evaporation of the water of hydration of the clay, which is progressively separated by attrition into particles of smaller and smaller size.

 In the disc-shaped wall 19, a diaphragm 25 is arranged which permits the
20 particles of small size to leave the enclosed space 14, whereas particles with larger dimensions are returned towards the chicanes in order to continue the disaggregation by attrition. It is therefore possible to regulate the device in order to recover, downstream of the diaphragm 25, a powder 26 whose particle size distribution is the natural particle size of the clay platelets. Typically, the powder 26
25 has dimensions of less than 100 μm , and it may even comprise at least 95% of particles with a dimension of less than 40 μm .

 At this stage, the powder generally no longer contains more than from 0 to 1% by weight of water. It has a lime reactivity, according to the Chapelle test, which is substantially unchanged in relation to the initial stage, generally less than
30 0.5 g per 1 g of pozzolan.

 The powder 26 and the gas stream 27, which has been cooled during the disaggregation operation (its temperature may fall to 100°C, but needs to be kept above its dew point) are recovered via a conduit 28, which may be directed towards a cyclone for optionally separating the particles of the powder as a

function of their size, for example in order to remove grains of sand or the aggregated particles with a dimension of more than 100 or 40 microns.

The powder 26 transported by the gas stream 27 may be stored at 5, after discharge of the transport gas, or may be sent directly to the heat treatment stage which follows.

In Figure 1, the powder is taken from the silo 5 and conveyed via a conduit 29, for example in a carrier gas stream, towards the transport conduit 6 in which a gas stream 30 produced by a burner 31 circulates, the said burner being located upstream of the conduit 6 so that the flame of the burner cannot extend into the zone where the powder is introduced. The flame of the burner 31 is regulated so that the temperature of the hot gas stream 30 in the conduit 6 is of the order of from 600 to 850°C, preferably of the order of from 600 to 800°C. The hot gas may be a combustion gas, as is the case here, but it could also be any other type of gas, air or the like, which is heated by any known means.

In order to disturb the thermal equilibrium in the conduit as little as possible, the powder may be conveyed into the conduit 29 by a hot gas stream.

The conduit 6 may be equipped with means for control and regulation of the temperature of the gases, for example in order to impose a temperature gradient along the conduit or, conversely, to keep the temperature within a small variation range. The conduit 6 will advantageously be provided with heating means, because the kaolin dehydroxylation reaction is endothermic and lowers the temperature of the treatment gas, and therefore that of the particles.

Hence, the conduit represented in Figure 1 is equipped with a heating jacket 32, which may consist of a double sleeve inside which a heating fluid circulates, in particular combustion gases. As a variant or in addition, electrical heating means may be provided.

Since the dehydroxylation reaction is endothermic, it may be beneficial in terms of thermal efficiency to provide an energy input into the particles transported in the flow. This energy input may be provided, in particular, by electrical radiation or by gaseous or liquid combustion of a fuel. (If a gas is used, it will spontaneously ignite in contact with the wall.)

The conduit is advantageously provided with external insulation (not shown) to counteract heat losses.

The conduit 6 is arranged in any known way that permits fluidisation of the powder particles, preferably vertically, and it is dimensioned so as to permit a sufficient residence time of the powder with the gas stream 30. This dimensioning depends, inter alia, on the material which is being treated, the particle size of which dictates the fluidisation rate, which is the minimum speed of the gas stream 30 for transporting the powder throughout the conduit. As an illustration, the speed of the gas 30 for treating clay may be of the order of 10 m/s.

The residence time of the powder in the conduit actually depends on the desired degree of dehydroxylation and the temperature of the gas 30, and it will therefore be adapted on a case-by-case basis by the person skilled in the art. A residence time -between 0.1 and 0.2 s at 800°C is generally sufficient to increase the Chapelle test value significantly, advantageously by at least 0.1 g, and in particular by approximatively 0.7 g to 0.8 g / g of pozzolan.

On the basis of a kaolin clay which, when leaving the grinder-dryer, already had a capacity to bind lime according to the Chapelle test with a reactivity, for example, of the order of 0.5 g, it was possible to verify that the treatment in the conduit 6 permits the dehydroxylation to be enhanced, increasing the reactivity of the powder.

The kinetic of the pozzolanic reaction (PR) of the dehydroxylated kaolin clay (metakaolin) has been determined according to following tests protocol.

A pure paste is prepared by mixing equal quantities of metakaolin and calcium hydroxide with water (weight of water / weight of solids is 0.68).

The paste obtained is cast in 4X4X4 cm cubes and cured at 100%H.R. at 20 °C, for 3 and 7 days.

After a 3-day and 7-day cure, hardened samples are ground and subjected to Differential Thermal Analysis(DTA) where the surface area of Ca(OH)_2 dehydration peak is measured.

Besides, the surface area of the Ca(OH)_2 dehydration peak is measured by DTA for a 1:1 mixture of Ca(OH)_2 and an inert component SiO_2 (reference).

The ratio between both peak areas indicates the amount of Ca(OH)_2 consumed by the pozzolanic reaction. The higher the amount of Ca(OH)_2 consumed, the higher the ratio between both peak areas. The pozzolanic reactivity is calculated as :

$$\text{PR (\%)} = ((\text{peak area of reference} - \text{peak area of material analysed}) / \text{peak area of reference}) \times 100$$

This method of measurement, which is well known by the person skilled in the art, was developed at Institut National de Sciences Appliquées de Lyon – France - (INSA-Lyon) by Prof. Jean Pera and Prof. Jean Ambroise (see for instance Jean Ambroise Phd Thesis – 1984 – *Elaboration de Liants Pouzzolaniques à Moyenne Température et Etude de leurs Propriétés Physico-Chimiques et Mécaniques*).

The metakaolin, as prepared above, exhibits a pozzolanic reactivity of 62% after a 3-day cure, and of 94% after a 7-day cure. For a comparison, a metakaolin was prepared from the same raw material but calcinated in a static process. The reactivity is as shown in table 1, along with the reactivity of some commercially available metakaolins;

The commercial metakaolin studied are: Metakaolin B : Metastar 501 from IMERYS

Metakaolin C : Polestar 400 from IMERYS

Metakaolin D : Glomax LL from IMERYS

Metakaolin E : Metamax from ENGELHARD

Table 1

	3- day reactivity PR (%)	7-day reactivity PR (%)	Chapelle Test Value (mg CaO/ g MK)
Kaolin A calcined according to the invention	62	94	746
Kaolin A calcined according to a static calcination process	30	86	710
Metakaolin B	19	82	785
Metakaolin C	0	29	397
Metakaolin D	21	25	269
Metakaolin E	39	91	828

The metakaolin calcined according to the invention has a higher early-age pozzolanic reactivity than the other metakaolins, including the metakaolin calcined by static process from the same kaolin source.

5 It can be noted that the metakaolin calcined according to the invention has also a higher early-age pozzolanic reactivity than the metakaolins giving the highest Chapelle values, that means, highest pozzolanic reactivity potential. (Metastar 501 from IMERYS and Metamax from ENGELHARD).

The treatment in the conduit 6 may also be used to impart reactivity to a material which is initially very unreactive.

10 Therefore, in another test, a kaolin powder marketed by the company SOKA under the brand name SIALITE, whose initial Chapelle reactivity is very low (of the order of 45 mg of CaO per gram), was treated using a gas at 800°C forced with a speed of 10 m/s through a 1.7 m long conduit, the degree of dehydroxylation being such that the Chapelle reactivity was 307 mg per 1 gram of material and, for a 5.1
15 m long conduit, a reactivity of 0.7g per 1 gram of dry material was achieved.

When leaving the conduit, the powder 26 and the gas 30 are still at an elevated temperature, and it may be desirable to cool them before proceeding with the separation of the powder. This is why the installation comprises a heat exchanger 7 connected to the outlet of the conduit 6, upstream of the filter 8 for
20 separating the dehydroxylated powder.

A hot gas recycling circuit, with the possibility of re-heating, may be provided in order to improve the thermal or energy efficiency of the installation.

Although it has been described more particularly with reference to the treatment of a kaolin clay, the invention is generally applicable to the treatment of
25 any material containing aluminium silicate.